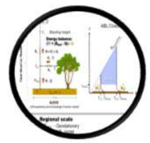
The 5th edition of the IESWG meeting, FMI Finland, September 26-28, 2023

All-sky Evapotranspiration Data Products from Satellite Observations for Taiwan Weather Models and Agricultural Drought Monitoring

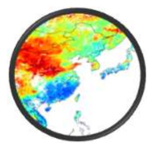
Li Fang, Xiwu Zhan, Jicheng Liu, Istvan Laszlo, *NOAA-NESDIS*
Christopher Hain, *NASA-MSFC*
Martha Anderson, *USDA-ARS*
Yu-Cheng Chang, Tony Liao*, CWA, Taiwan*

OUTLINE

All-sky Evapotranspiration Data Products from Satellite Observations for Taiwan Weather Models and Agricultural Drought Monitoring



GET-D and ALEXI Model



GET-D for Taiwan Weather Models

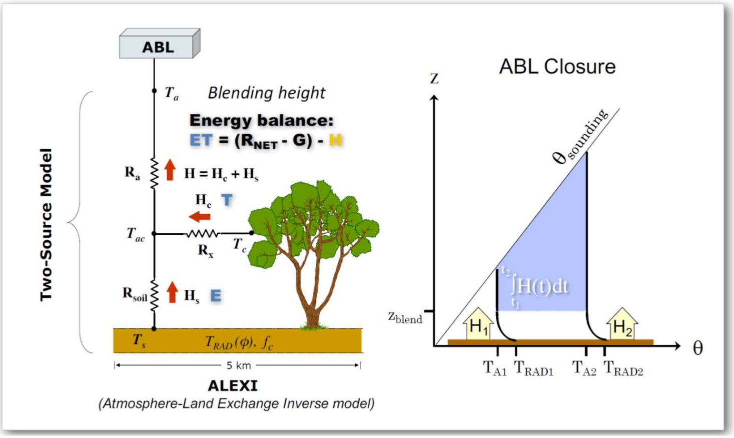
GET-D Clear-sky vs. All-sky

Products Validation & Unique advantages

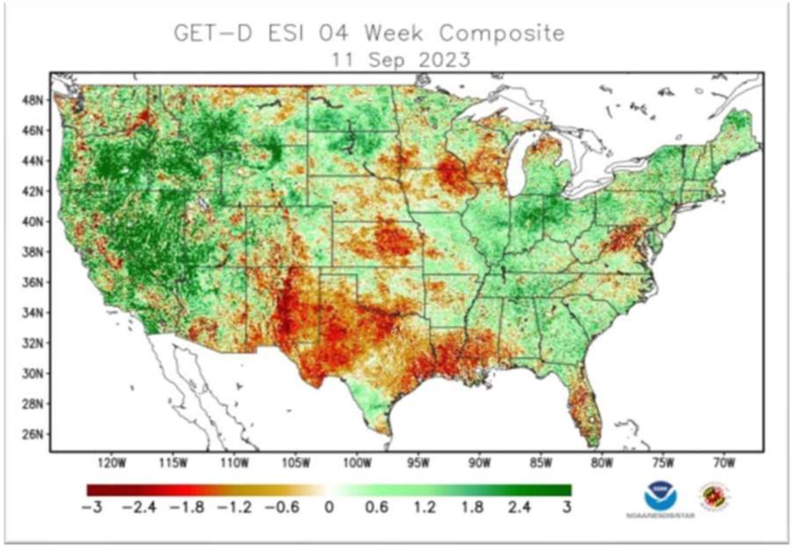
GOES ET and Drought Monitoring System (GET-D)

- **Atmosphere-Land Exchange Inversion (ALEXI)**: a diagnostic modeling approach, built on the two-source energy balance model, to exploit the mid-morning rise in temperature to derive the land surface fluxes, including ET
- **Evaporative stress index (ESI):** indicates how the current rate of ET compares to long-term climatology; Negative ESI values show below normal ET rates, indicating vegetation that stressed due to inadequate soil moisture, and vice versa

ALEXI Model



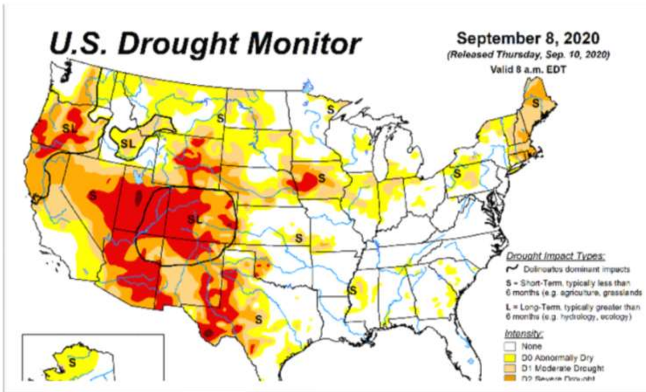
GET-D ESI

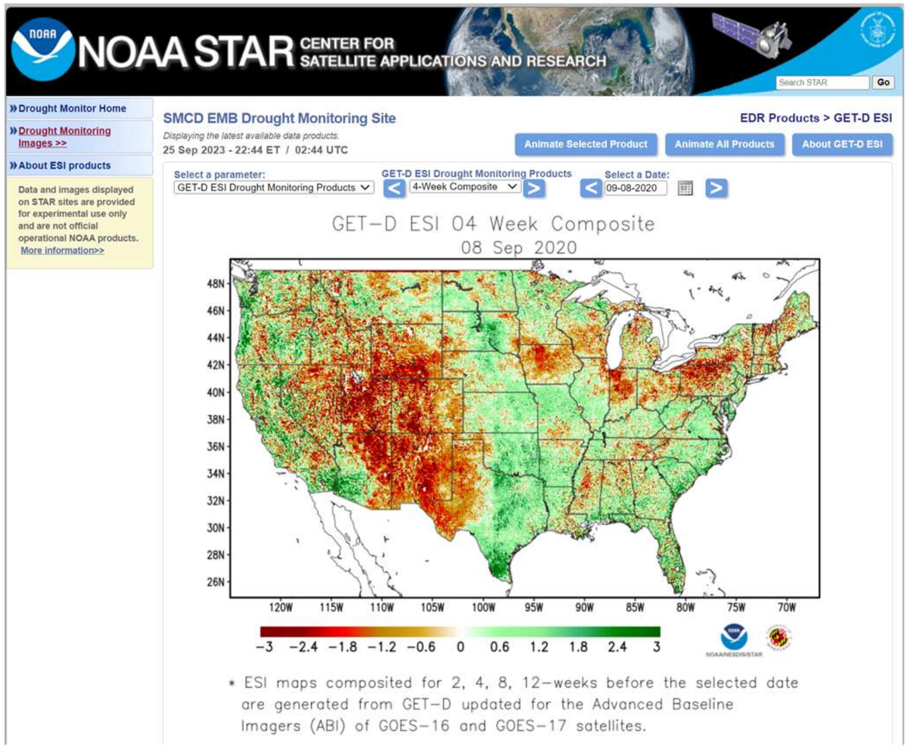


[STAR GET-D web page]

GOES ET and Drought Monitoring System (GET-D)

GET-D ESI 4-week composite on Sept. 8, 2020, compared with U.S. Drought Monitor Map



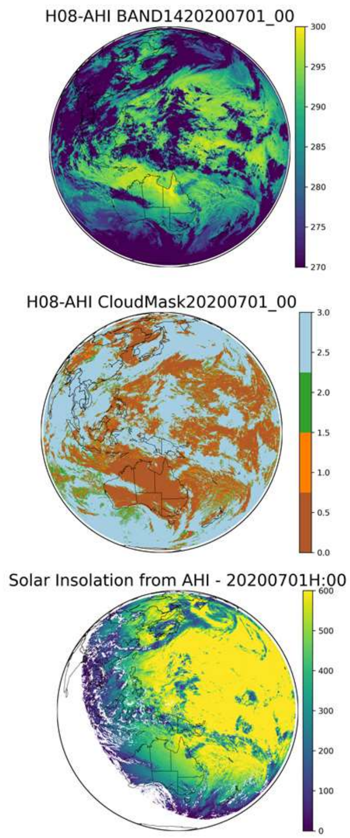


- NOAA NESDIS GET-D product system was operationally generating ET and drought maps at 8 km resolution using GOES-13/15 observations since 2016
- Current GET-D experimental system routinely generates ET and ESI over Contiguous US (CONUS) at 2 km resolution using GOES-16/18 Advanced Baseline Imager (ABI) observations

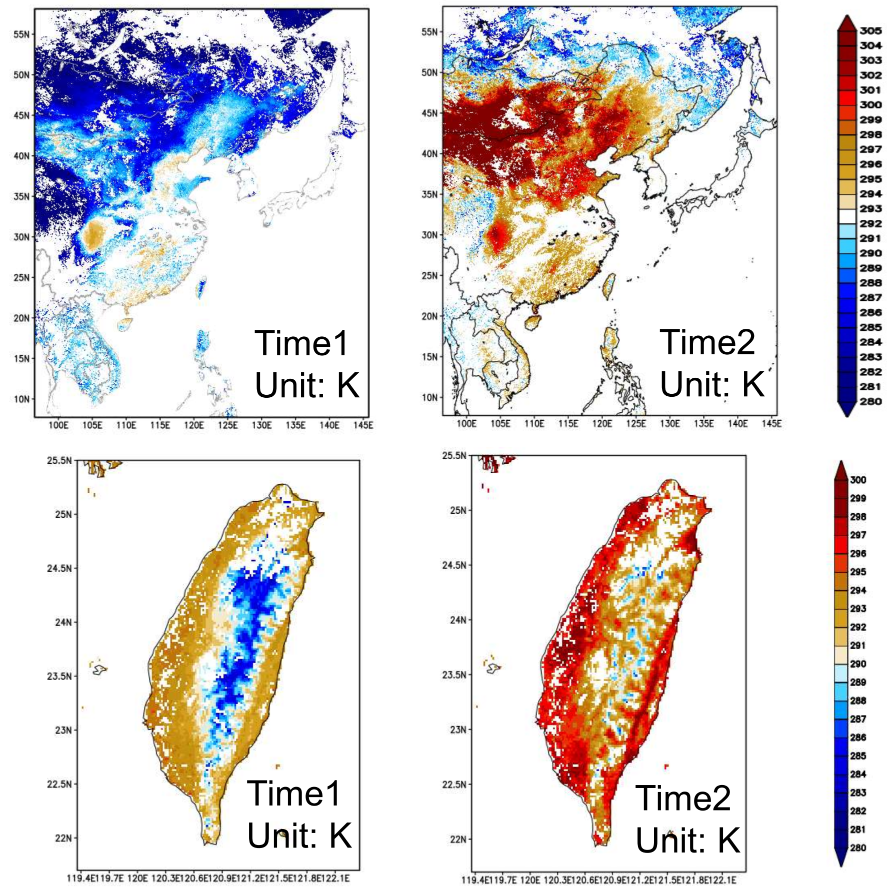
[STAR GET-D web page]

GET-D for Taiwan Central Weather Administration

- The GOES-based GET-D system has been reconfigured for observations from the Advanced Himawari Imager (AHI) for Taiwan Central Weather Administration (CWA)
- GETD4CWB system generates daily ET at 2km spatial resolution over Taiwan region



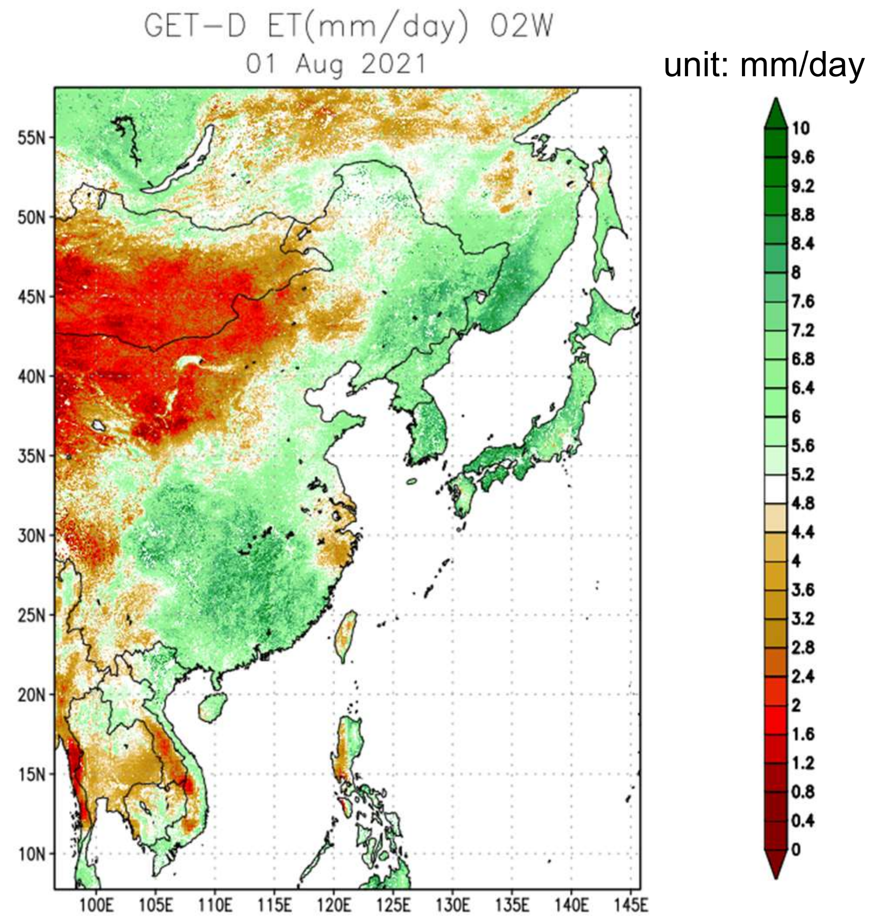
Three Major Himawari-8 Inputs:
BT, Cloud Mask & DSR
Full Disk at 2 km



Extract Clear-sky LST at morning rise hours
Time 1: 1.5 hour after sunrise
Time 2: 1.5 hour before noon

GET-D using AHI for Taiwan Weather Models

- The GETD4CWB system has been demonstrated fully functional to map ET using AHI
- GETD4CWB ET estimates have been evaluated using in-situ observations over 20 stations in Taiwan region
- The GETD4CWB system (v1.0) has been delivered to Taiwan Central Weather Bureau, as well as supporting documents



OUTLINE

All-sky Evapotranspiration
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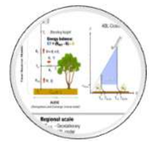
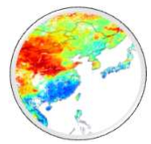


GET-D and ALEXI Model



GET-D for Taiwan Weather Models

GET-D Clear-sky vs. All-sky

Products Validation & Unique advantages

Clear-sky and all-weather GET-D Systems

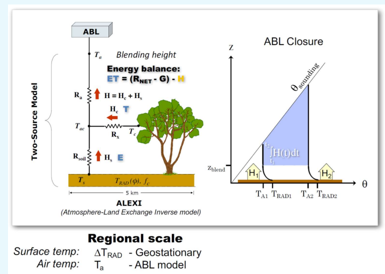
*Predictions based on **physical model***

Thermal Obs
GOES-R

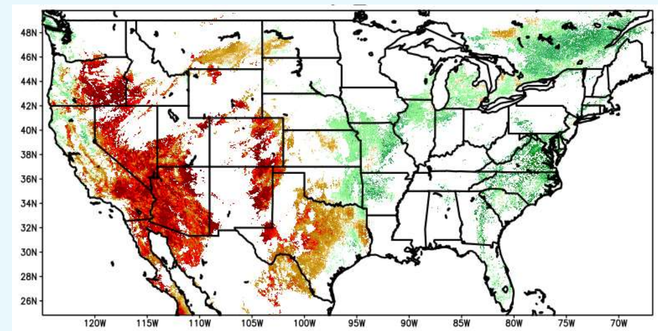
Ancillary

Cloud
Filter

Land-atmospheric model



Clear-sky ET Product



*Predictions based on **machine learning***

Thermal Obs
GOES-R

Ancillary

Cloud?

NO

YES

Apply MW/LSM RT

AMSR2
2km

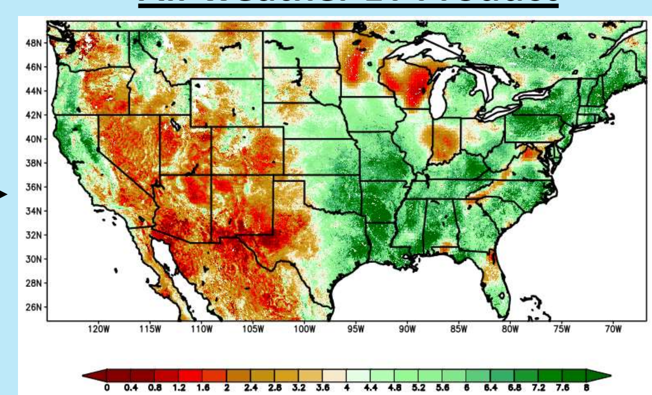
MW/LSM RT

Apply LSM/TIR RT

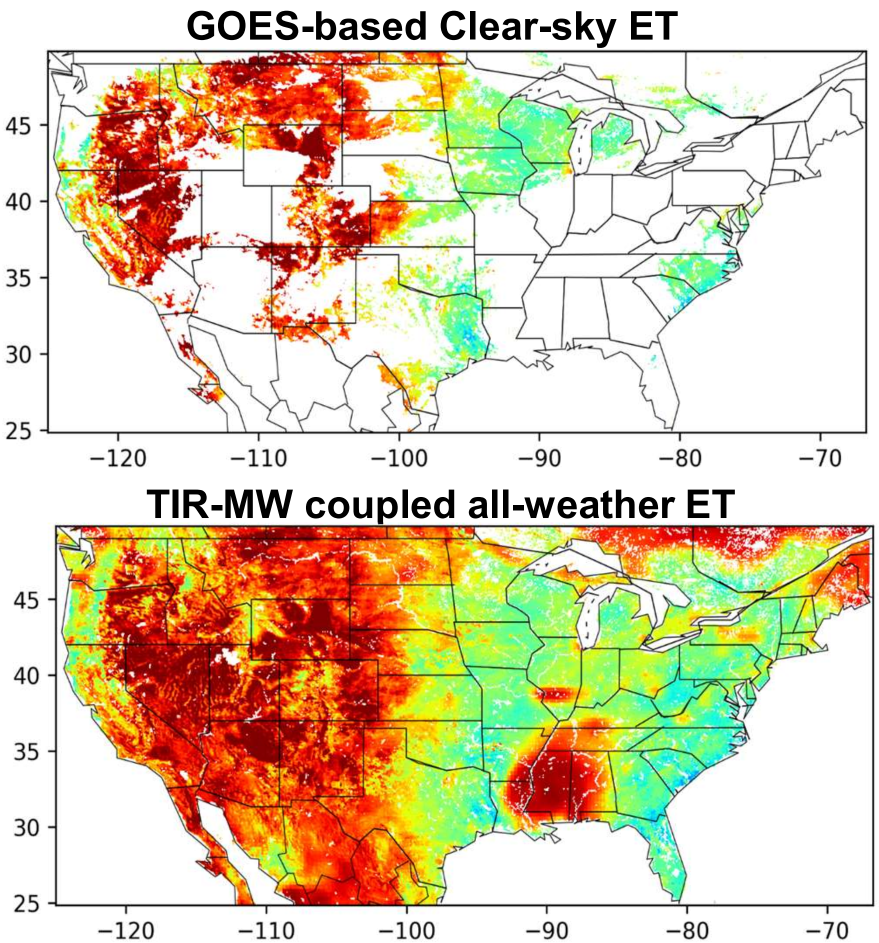
AMSR2
Predicted
CFSR

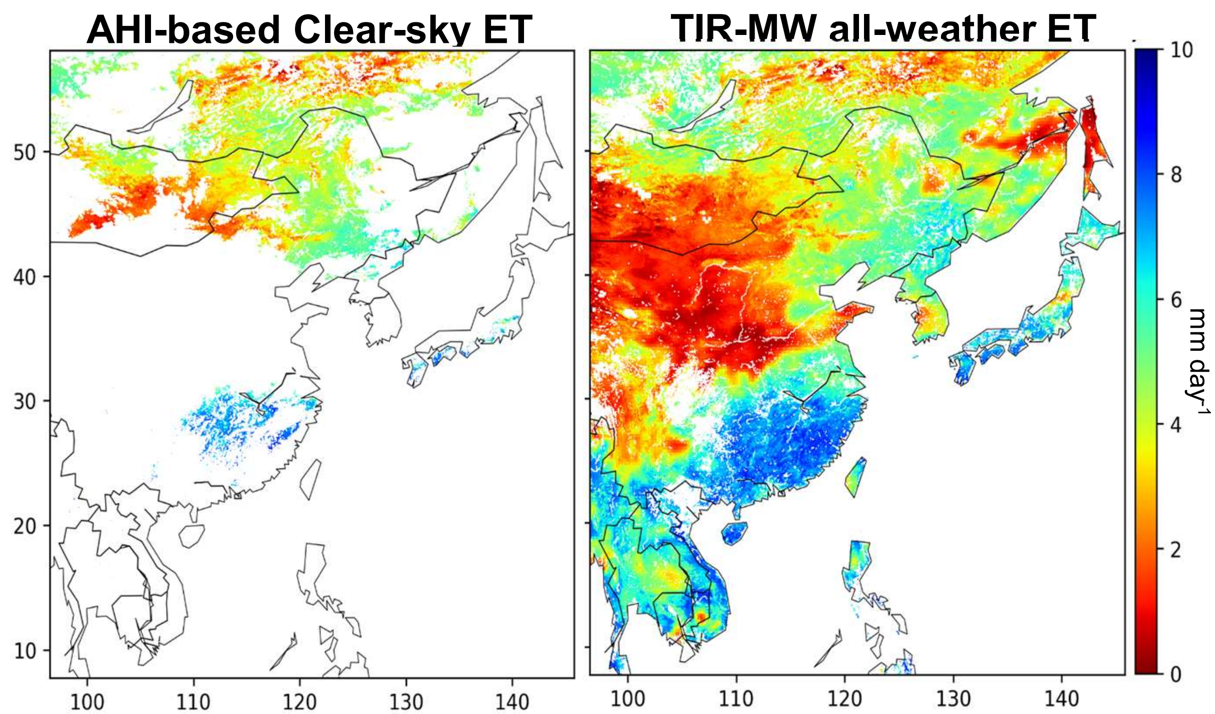
LSM/TIR RT

All-weather ET Product



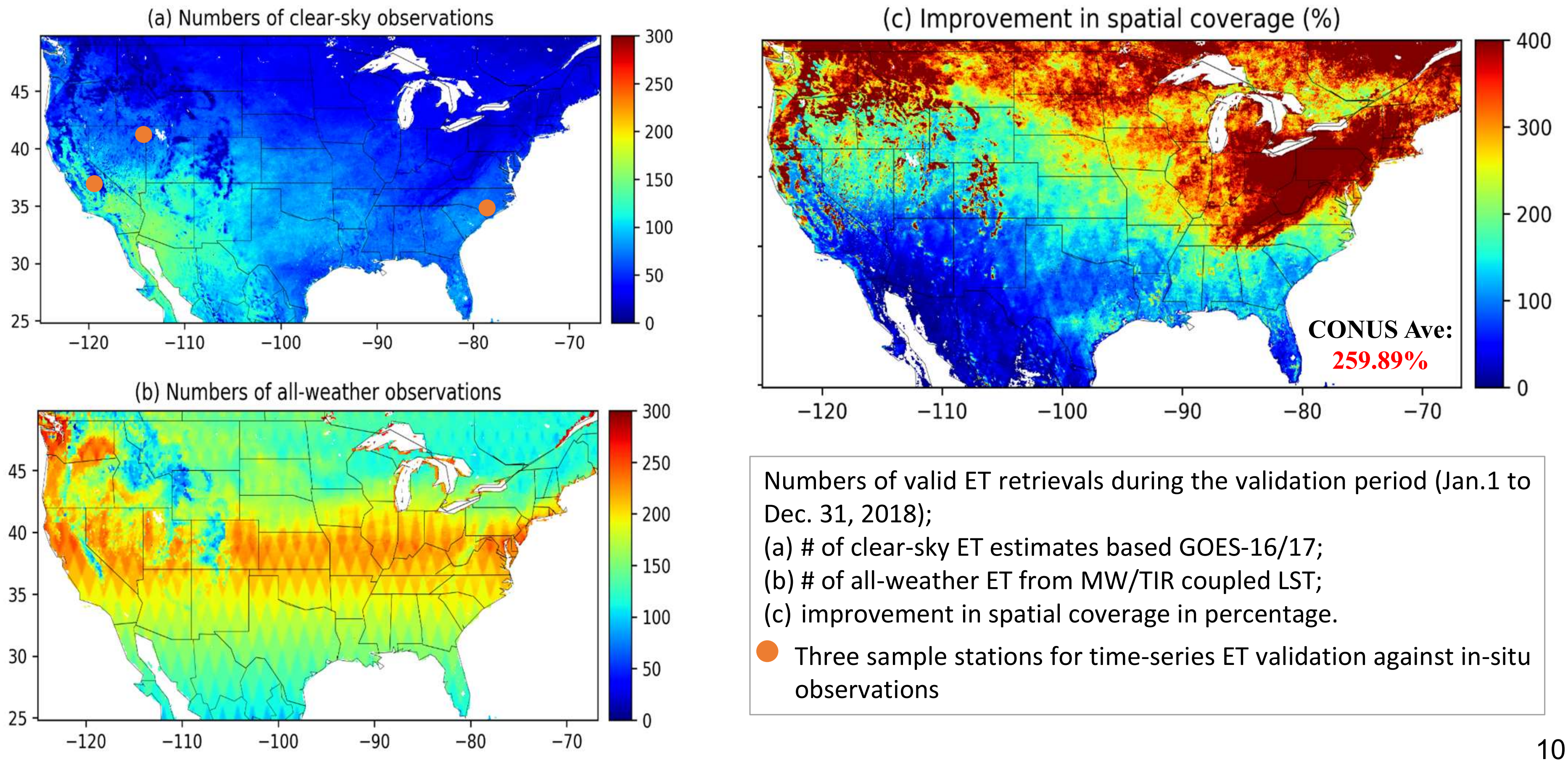
Clear-sky/all-weather ET Products over CONUS and East Asia





Aug. 30, 2021 Comparison of:
<u>Clear-sky</u> ET (derived from GOES-ABI and H08-AHI), and
<u>All-weather</u> ET (derived from PMW and thermal combined LST)

Improvement in data coverage



Numbers of valid ET retrievals during the validation period (Jan.1 to Dec. 31, 2018);
(a) # of clear-sky ET estimates based GOES-16/17;
(b) # of all-weather ET from MW/TIR coupled LST;
(c) improvement in spatial coverage in percentage.

● Three sample stations for time-series ET validation against in-situ observations

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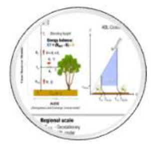
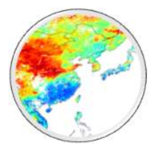
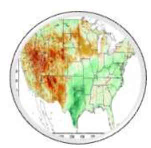


GET-D and ALEXI Model



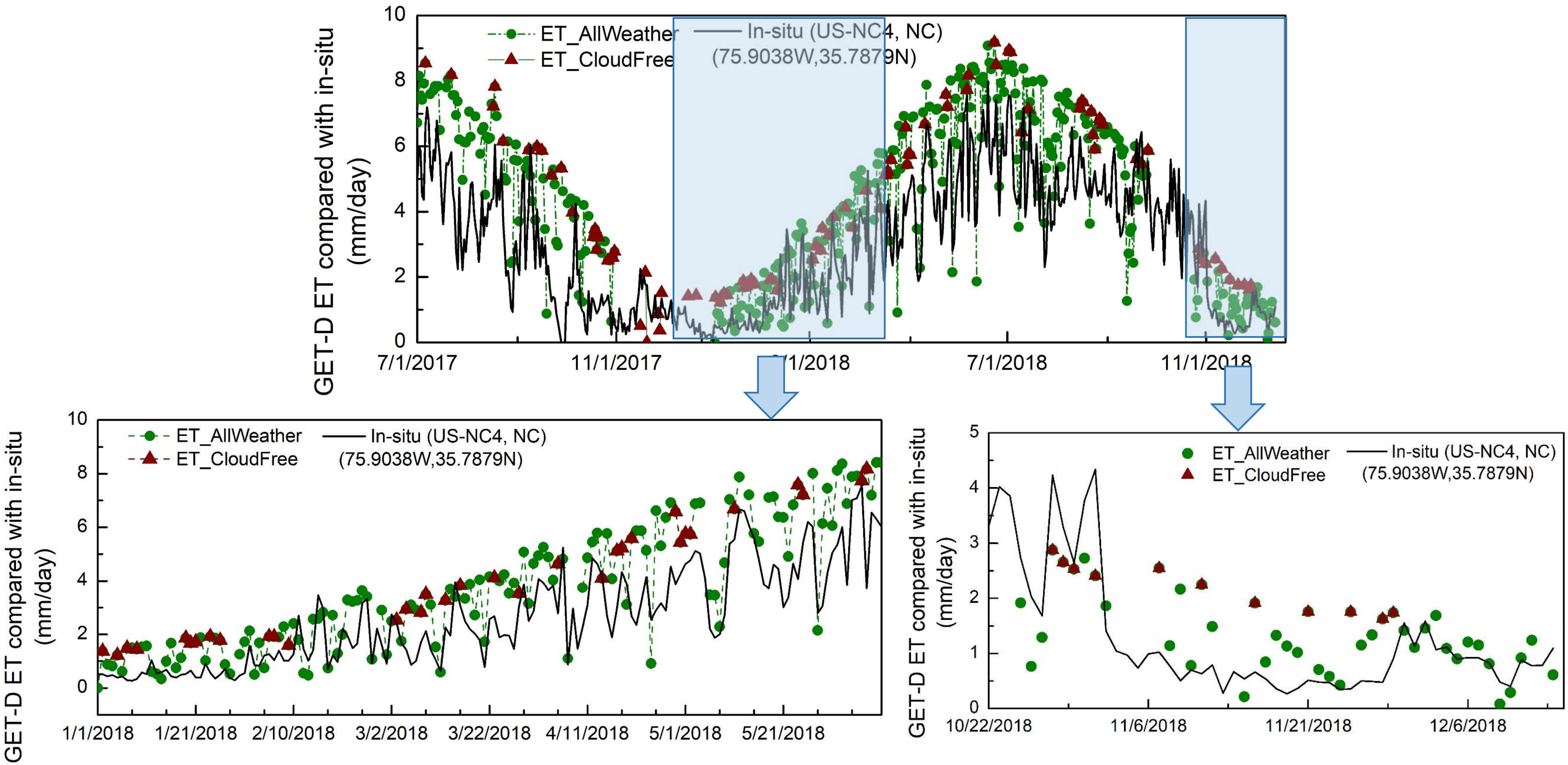
GET-D for Taiwan Weather Models



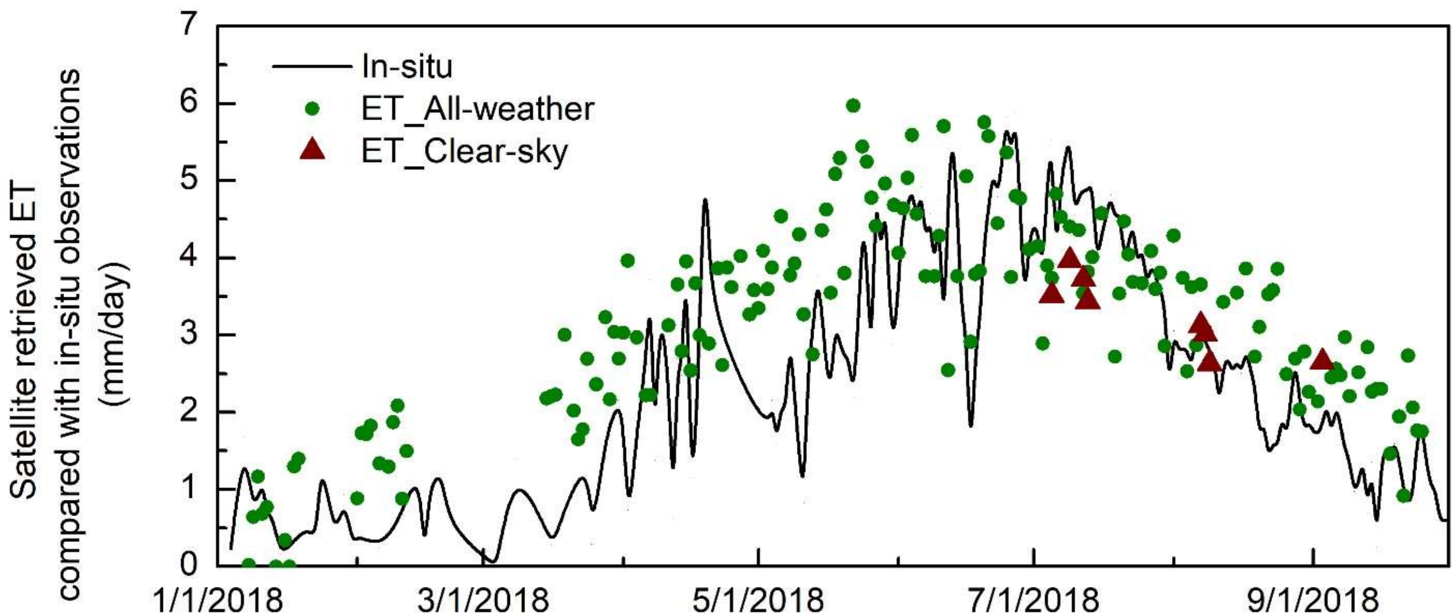
GET-D Clear-sky vs. All-sky

Products Validation & Unique advantages

Validation of clear-sky & all-weather ET



Validation of clear-sky & all-weather ET



Time series comparison of clear-sky ET (derived from GOES16/17) and all-weather ET (derived from GOES&AMSR2&CFSR combined LST), along with in-situ ET observations at the US-Rms station in ID; Jan. 1 to Dec. 31, 2018; Unit: mm/day

Error statistics – over U.S.

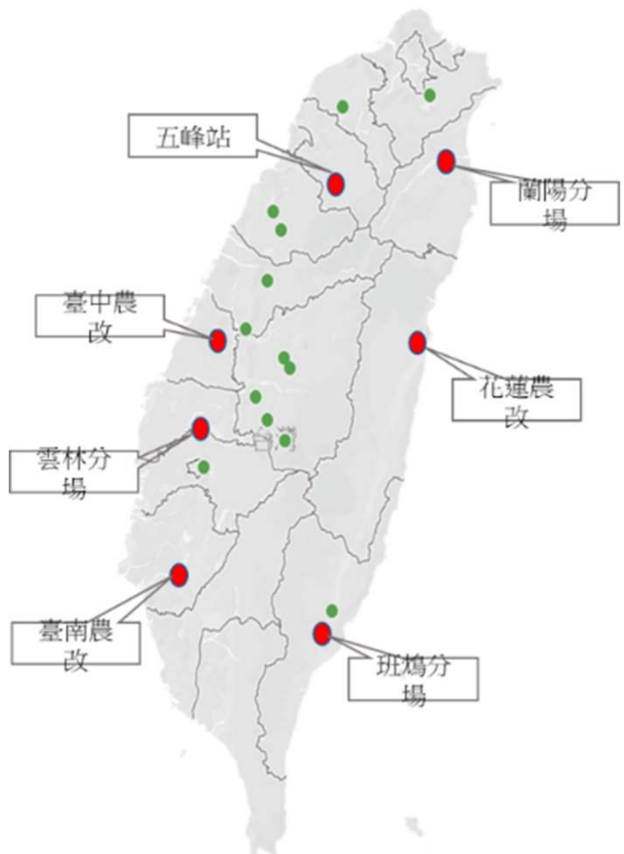
Station ID	LAT	LON	Correlation		RMSE(mm/day)	
			clear-sky	all-weather	clear-sky	all-weather
US-ARM	36.6058	-97.4888	0.8713	0.7431	0.9248	1.1754
US-Bi1	38.0992	-121.499	0.6267	0.7542	1.5537	1.3975
US-Bi2	38.109	-121.535	0.8202	0.7988	1.0228	1.147
US-Hn2	46.6889	-119.464	0.3981	0.4971	1.7704	1.4885
US-Me6	44.3233	-121.608	0.754	0.6064	1.2159	1.5778
US-NC2	35.803	-76.6685	0.9363	0.7726	2.011	2.2386
US-NC3	35.799	-76.656	0.861	0.7896	1.368	1.7162
US-NC4	35.7879	-75.9038	0.8155	0.7932	1.8388	2.1315
US-Rls	43.1439	-116.736	0.5908	0.6188	1.2332	1.2201
US-Rms	43.0645	-116.749	0.9401	0.778	0.9644	1.1715
US-Ro4	44.6781	-93.0723	0.8112	0.7428	1.4993	1.5841
US-Ro5	44.691	-93.0576	0.8248	0.6941	0.8241	1.226
US-Ro6	44.6946	-93.0578	0.772	0.7236	0.765	1.1051
US-Rws	43.1675	-116.713	0.6555	0.6881	1.2345	1.217
US-Sne	38.0369	-121.755	0.9025	0.9192	0.8479	0.7711
US-SRG	31.7894	-110.828	0.8084	0.6833	0.924	1.1197
US-SRM	31.8214	-110.866	0.8513	0.6914	0.6331	0.9114
US-Ton	38.4316	-120.966	0.7882	0.8719	3.8337	3.57
US-Tw3	38.1159	-121.647	0.2336	0.3846	1.7012	1.8738
US-Tw4	38.103	-121.641	0.8336	0.8375	2.319	2.0059
US-Var	38.4133	-120.951	0.4627	0.5952	1.9449	2.0997
US-WCr	45.8059	-90.0799	0.8216	0.7176	0.9867	1.68
US-Whs	31.7438	-110.052	0.4372	0.5785	1.1942	1.1607
US-Xha	42.5369	-72.1727	0.6365	0.5238	2.495	2.4008
Average			**0.727213**	**0.700142**	**1.462733**	**1.582892**

Fang L, Zhan X, Schull M, Kalluri S, Laszlo I, Yu P, Carter C, Hain C, Anderson M. Evapotranspiration Data Product from NESDIS GET-D System Upgraded for GOES-16 ABI Observations. *Remote Sensing*. 2019; 11(22):2639. https://doi.org/10.3390/rs11222639

Fang L, Zhan X, Kalluri S, Yu P, Hain C, Anderson M and Laszlo I (2022) Application of a Machine Learning Algorithm in Generating an Evapotranspiration Data Product From Coupled Thermal Infrared and Microwave Satellite Observations. *Front. Big Data* 5:768676. doi: 10.3389/fdata.2022.768676

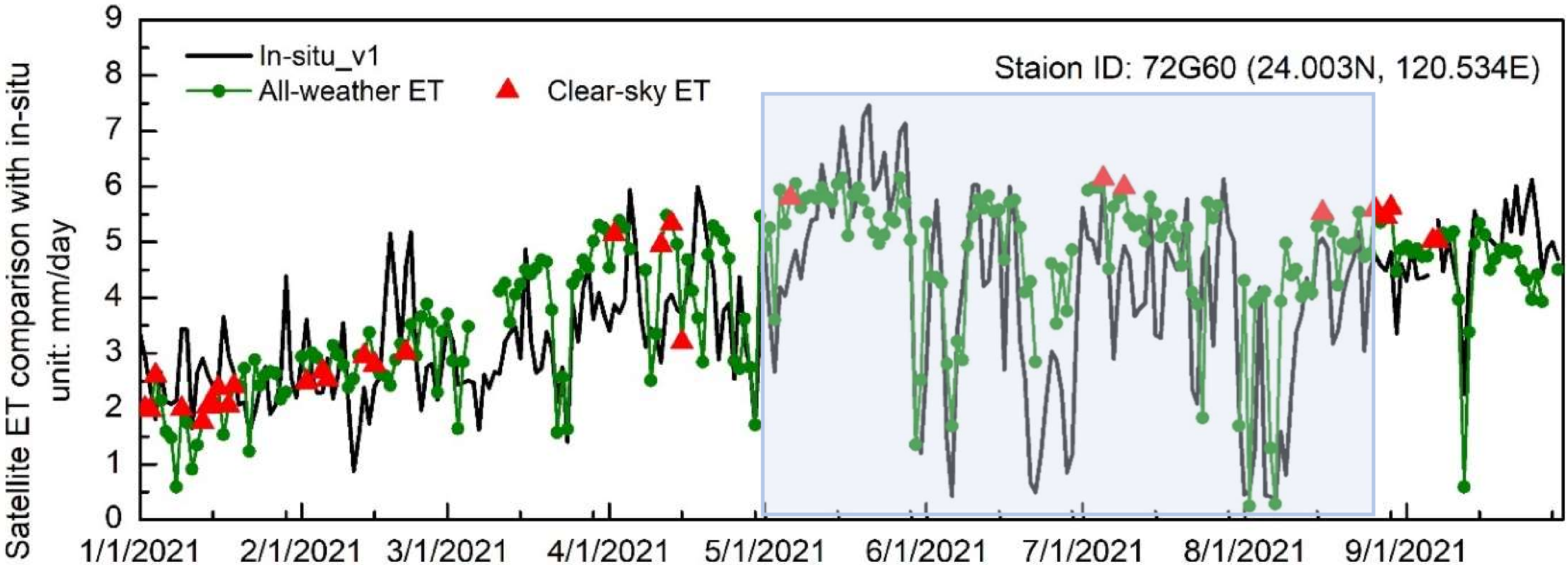
Validation of GETD4CWB ET over Taiwan Region

- With the help of CWA team, ground daily ET observations over Taiwan region have been obtained
- STAR and CWA science teams have been working together on the in-situ daily ET integration and comparison with satellite ET estimates



項次	測站代碼	測站中文名稱	經度_WGS84	緯度_WGS84	海拔(橢球高)(m)
1	72S20	斑鳩分場	121.078	22.8295	240
2	82S58	臺東茶改	121.13	22.9077	175
3	U2H48	臺大溪頭	120.798	23.6703	1150
4	72G60	臺中農改	120.534	24.003	19
5	72K22	雲林分場	120.477	23.6346	60
6	72N10	臺南農改	120.342	23.0605	41
7	72D08	五峰站	121.157	24.6122	1048
8	82C16	茶改場	121.185	24.9085	195
9	82A75	文山茶改	121.631	24.9558	401
10	72U48	蘭陽分場	121.717	24.6863	27
11	K2E36	苗栗農改	120.829	24.4957	100
12	K2E71	大湖分場	120.872	24.4229	286
13	K2F75	種苗繁殖	120.801	24.226	470
14	82H84	凍頂茶改	120.741	23.7625	390
15	82H32	魚池茶改	120.914	23.8756	850
16	G2L02	嘉義農試	120.474	23.485	79
17	72T25	花蓮農改	121.564	23.9752	36
18	E2H36	蓮華池	120.885	23.9183	681
19	U2HA3	臺大和社	120.889	23.5909	772
20	G2F82	農業試驗所	120.688	24.0313	90

Validation of GETD4CWB ET over Taiwan Region

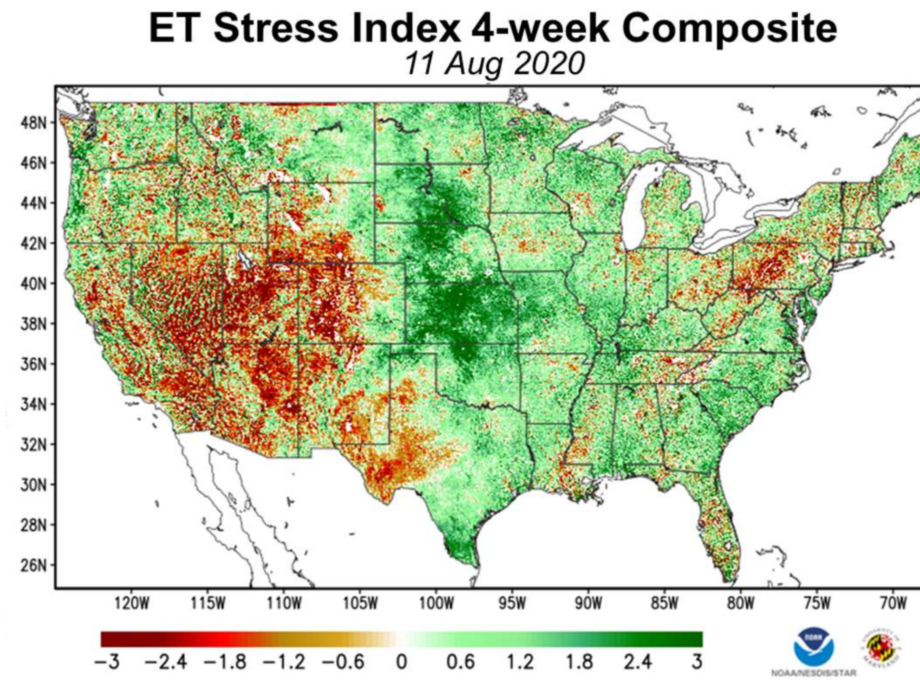


Time series comparison between GETD4CWB estimates and in-situ ET measurements over the Station 72G60 from Jan. 1 to Oct. 1, 2021

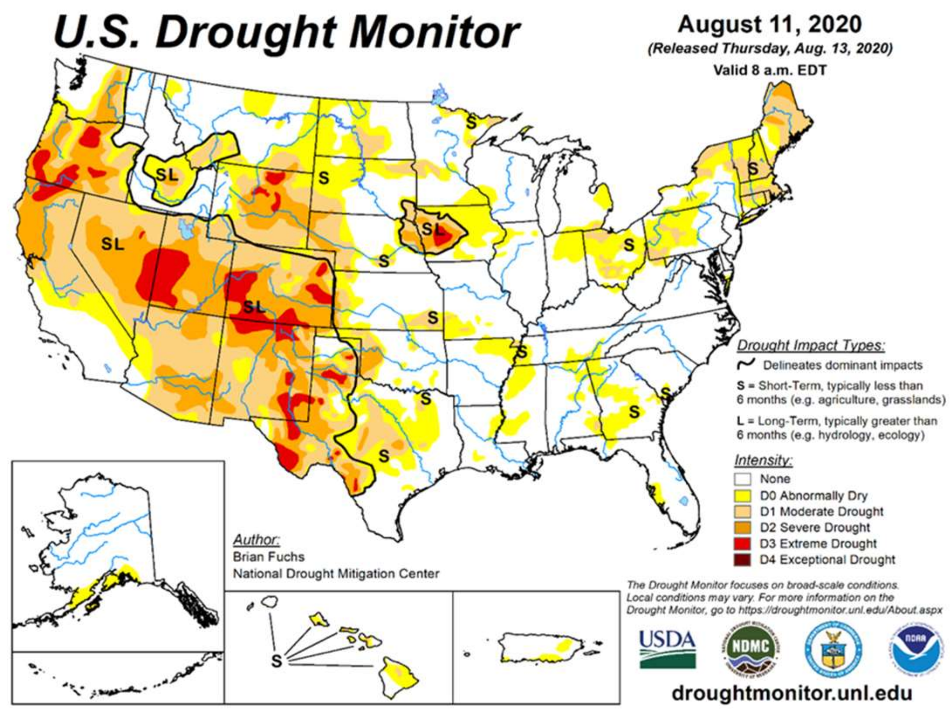
Validation of GETD4CWB ET over Taiwan Region

Station ID	LAT	LON	Correlation		Bias		RMSE		UbRMSE		Sample N	
			Clear-sky	All-weather	Clear-sky	All-weather	Clear-sky	All-weather	Clear-sky	All-weather	Clear-sky	All-weather
72D08	24.6122	121.157	0.49	0.44	1.60	2.92	2.38	3.52	1.76	1.96	28	264
72G60	24.003	120.534	0.81	0.65	0.08	0.38	0.93	1.25	0.92	1.19	28	264
72K22	23.6346	120.477	0.47	0.53	1.49	1.36	2.06	1.94	1.42	1.39	43	259
72N10	23.0605	120.342	0.73	0.62	1.13	1.58	1.55	2.05	1.05	1.31	34	263
72S20	22.8295	121.078	0.19	0.18	1.56	1.18	2.32	2.47	1.72	2.16	37	260
72T25	23.9752	121.564	0.79	0.59	1.07	0.87	1.42	1.68	0.94	1.44	31	266
72U48	24.6863	121.717	0.68	0.71	0.83	1.28	1.45	1.88	1.19	1.39	27	263

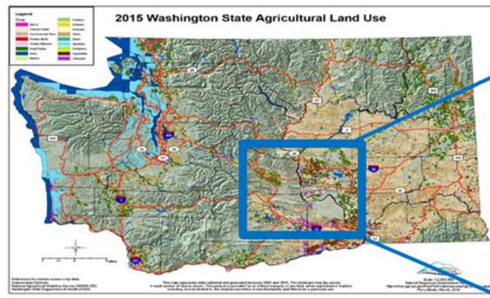
Comparison of GET-D ESI and USDM Products



* ESI maps composited for 2, 4, 8, 12−weeks before the selected date are generated from GET−D updated for the Advanced Baseline Imagers (ABI) of GOES−16 and GOES−17 satellites.

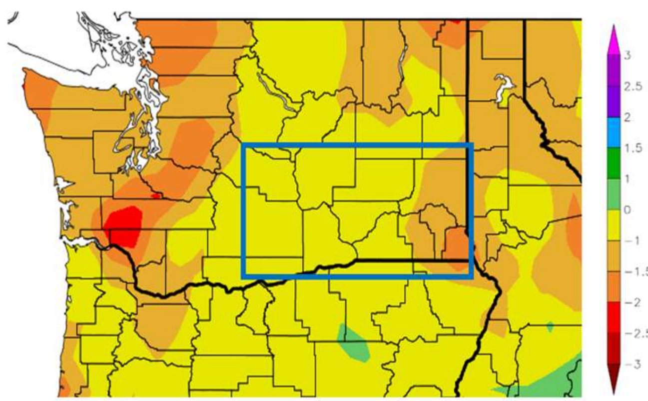


Capability of capturing irrigation activities

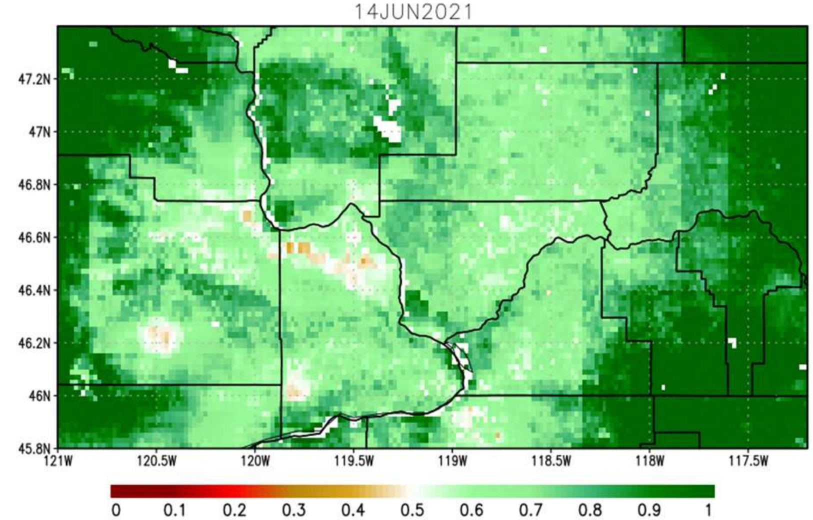


Agricultural fields in Columbia Basin, Washington

Monthly SPI (7/1/2021 – 7/31/2021, shaded)



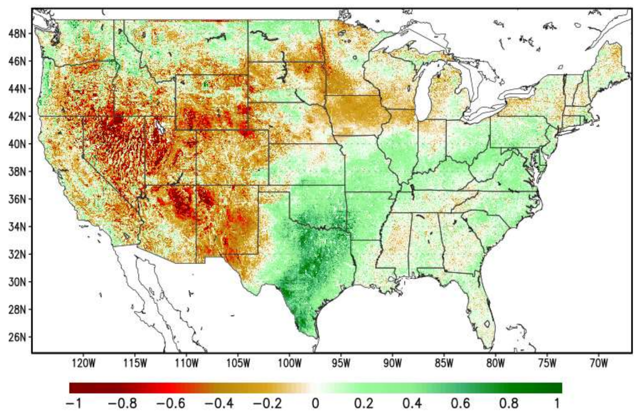
GET-D ESI over Crop Land in Columbia Basin, Washington June 14 – July 31, 2021



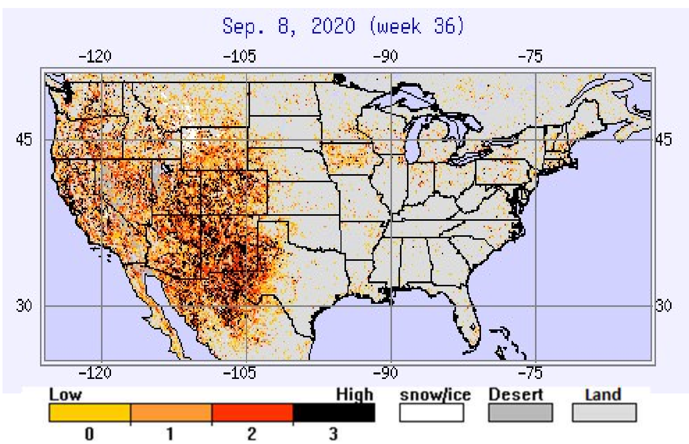
- GET-D ESI **does not require precipitation data**, derived directly from remotely sensed land surface temperature
- GET-D ESI inherently includes non-precipitation related surface water signals such as **irrigation activities, groundwater supplied vegetation**, etc.

Early Warning of Agricultural Drought

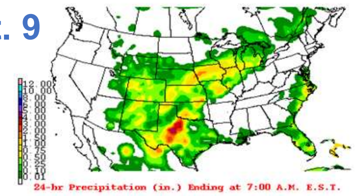
GET-D ESI (Sep. 8, 2020)



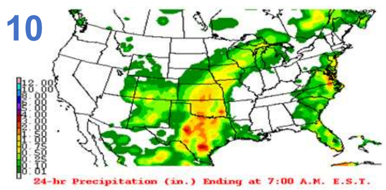
Vegetation Health based Drought (VHD)



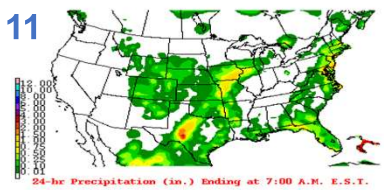
Sept. 9



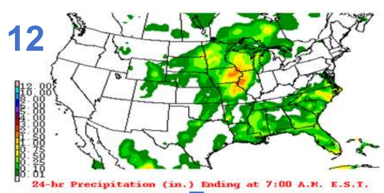
Sept. 10



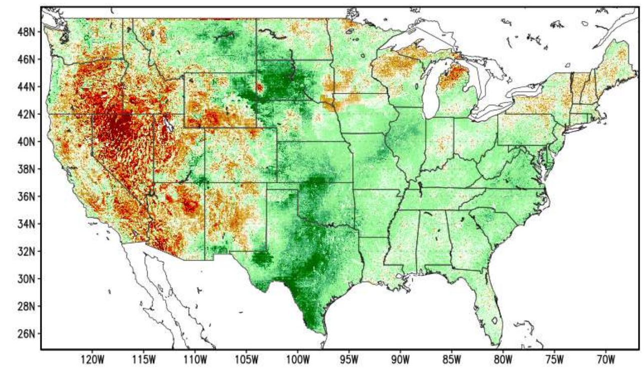
Sept. 11



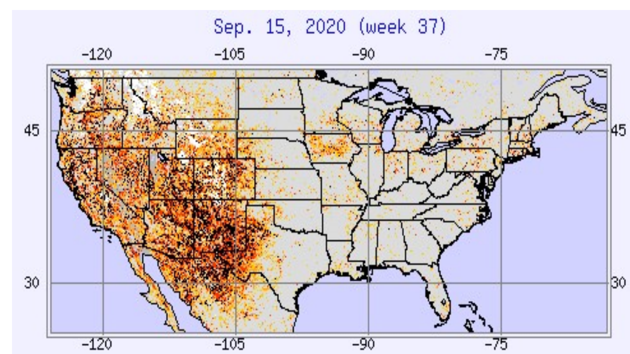
Sept. 12



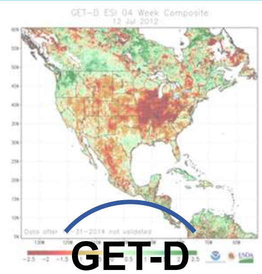
GET-D ESI (Sep. 15, 2020)



Vegetation Health based Drought (VHD)

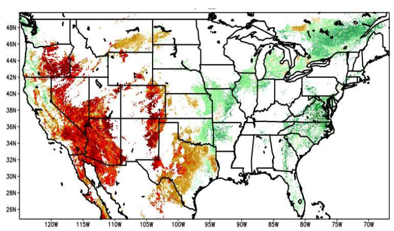


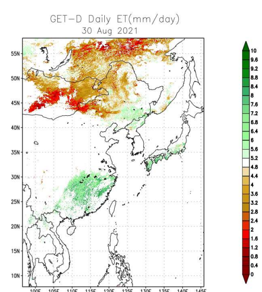
Summary and Future Steps

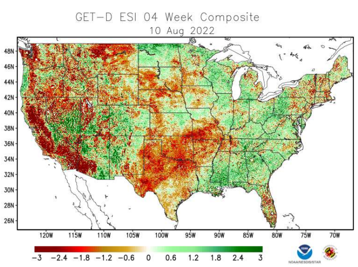


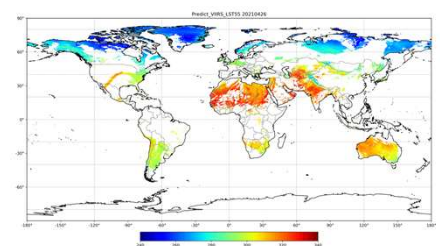
GET-D
GOES13/15; 8 km

GET-D	GETD4CWB	GETD-All-sky	GET-D
GOES16/18; 2 km	Asian; 2 km	2 km	Global; 1 km









END

Thanks for your attention!

Questions?
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